

PART THREE

SURFACE DRAINAGE

CHAPTER 7

SURFACE DRAINAGE REQUIREMENTS

7-1. General.

a. Considerations. The primary consideration for a surface drainage system is storm drainage. Other considerations include snow melting and man-made water sources such as washracks and sprinkler systems. The governing factor for sizing the system will be storm intensity.

b. Natural drainage. The maximum use of natural drainage should be considered. Runoff from runways, roads, taxistrips, aprons, and railroads should be collected in open channels or ditches for removal from the immediate area to the greatest extent possible. The use of buried pipe should be kept to a minimum and "daylighted" to open channel drainage as soon as practical.

c. Area drains. The use of area drains and box inlets in paved areas should be minimized, and collection piping under slabs or pavement systems should be as short as possible.

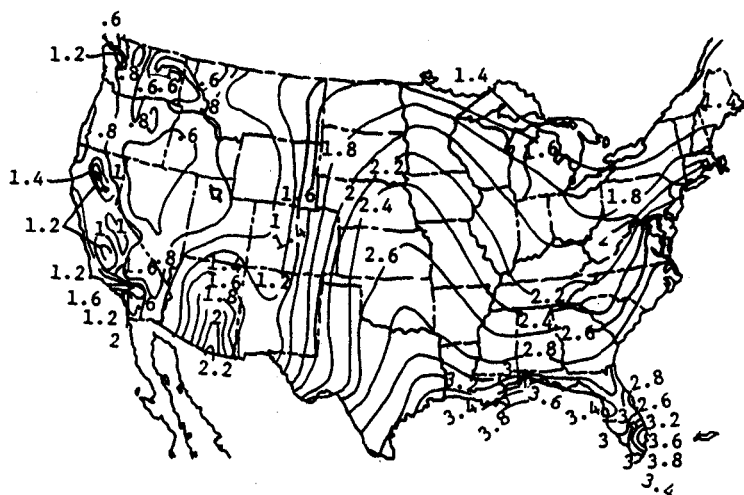
d. Storm and sanitary sewer systems. Combined storm and sanitary sewer systems should not be used.

7-2. Design storm.

a. Intensity-frequency data. Studies of rainfall intensity-frequency data indicate there is a fairly consistent relation between the average intensities of rainfall for a period of 1 hour and the average intensities at the same frequency for periods less than 1 hour, regardless of the geographical location of the stations. The average rainfall for a 1-hour period at various frequencies for the continental United States, and Alaska, may be determined from figure 7-1. A 10-year frequency and a 1-hour rainfall intensity is considered the design storm index for mobilization conditions.

b. Standard rainfall intensity-duration curves. Figure 7-2 shows the standard curves which have been developed to express the rainfall intensity duration relationships which are satisfactory for the design of drainage systems. The curves may be used for all locations until standard curves are developed for any region under consideration. As an example, assume the average rainfall intensity required for a 40-minute design storm based on a 10-year frequency in central Kentucky is found to be 2.0 in/hr. In figure 7-2, supply curve 2.0 is used with

10-YEAR 1-HOUR RAINFALL (INCHES)



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----- APPROXIMATE SOUTHERN LIMIT OF THE ARCTIC
..... APPROXIMATE SOUTHERN LIMIT OF PERMAFROST

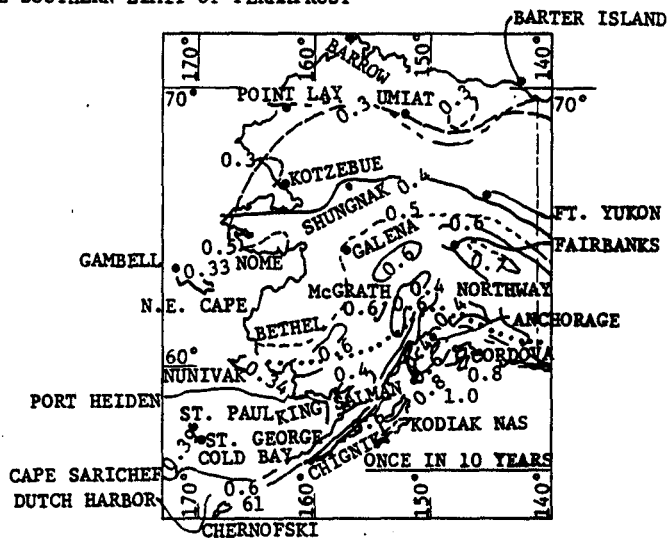
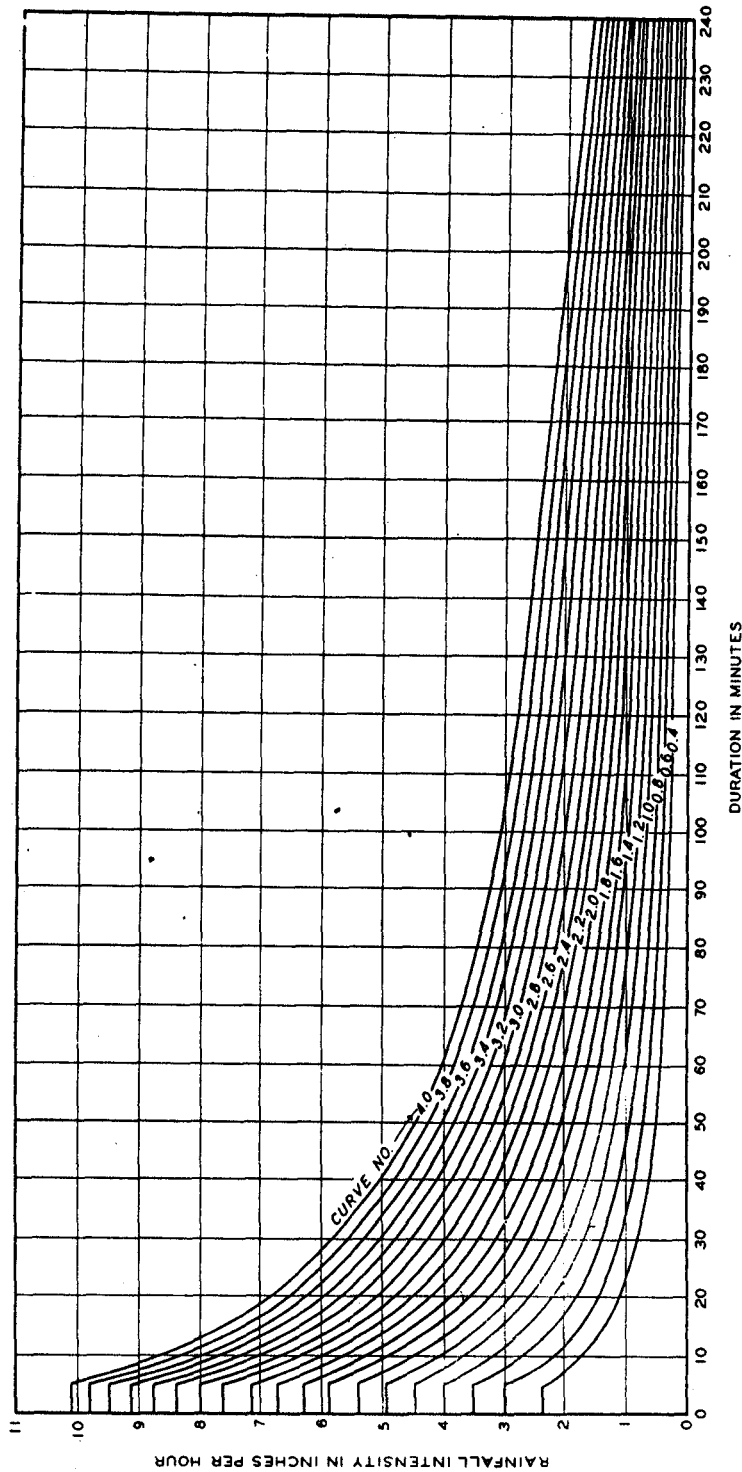


CHART REPRODUCTION FROM U.S. WEATHER BUREAU TECHNICAL PAPER NO. 40,
RAINFALL FREQUENCY ATLAS OF THE UNITED STATES, WASHINGTON, D.C., MAY 1961.

FIGURE 7-1. DESIGN STORM INDEX - 1 HOUR RAINFALL INTENSITY FREQUENCY
DATA FOR CONTINENTAL UNITED STATES AND ALASKA



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FIGURE 7-2. STANDARD RAINFALL INTENSITY DURATION CURVES
OR STANDARD SUPPLY CURVES

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the 40-minute duration of storm to determine a rainfall intensity of 2.7 in/hr.

7-3. Infiltration. Infiltration refers to the rate of absorption of rainfall into the ground during a design storm which is assumed to occur after a 1-hour period of antecedent rainfall. Wherever possible determine average infiltration rates from a study of runoff records near the area in question from infiltrometer studies or from similar acceptable information. Suggested mean values of infiltration for generalized soil classifications are shown in table 7-1. The soil group symbols are those given in Unified Soil Classification System for Roads, Airfields, Embankments, and Foundations.

Table 7-1. Infiltration Rate for Generalized Soil Classifications (Uncompacted)

Description	Soil Group Symbol	Infiltration, in/hr
Sand and gravel mixture	GW, GP SW, SP	0.8-1.0
Silty gravels and silty sands to inorganic silt, and well-developed loams	GM, SM ML, MH OL	0.3-0.6
Silty clay sand to sandy clay	SC, CL	0.2-0.3
Clays, inorganic and organic	CH, OH	0.1-0.2
Bare rock, not highly fractured	--	0.0-0.1

Infiltration values are for uncompacted soils. Where soils are compacted, infiltration values decrease; percentage decrease ranges from 25 to 75 percent, depending on the degree of compaction and the types of soil. Vegetation generally decreases infiltration capacity of coarse soils and increases that of clayey soils. The infiltration rate after 1-hour of antecedent rainfall for turfed areas is approximately 0.5 in/hr and seldom exceeds 1.0 in/hr. The infiltration rate for paved or roofed areas, blast protective surfaces, and impervious dust-palliative-treated areas is zero.

7-4. Rate of supply. Rate of supply refers to the difference between the rainfall intensity and the infiltration capacity at the same instant for a particular storm. To simplify computations, the rainfall intensity and the infiltration capacity are assumed to be uniform

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during any specific storm. Thus the rate of supply during the design storm will also be uniform.

a. Average rate of supply. Average rates of supply corresponding to storms of different lengths and the same average frequency of occurrence may be computed by subtracting estimated infiltration capacities from rainfall intensities represented by the selected standard rainfall intensity-duration curve in figure 7-2. For convenience, and since no appreciable error results, standard supply curves are assumed to have the same shapes as those of the standard rainfall intensity-duration curves shown in figure 7-2. For example, if Supply Curve 2.2 in figure 7-2 were selected as the design-storm and the infiltration loss during a 1-hour storm were estimated as 0.6 inch, curve 1.6 would be adopted as the standard supply curve for the given areas.

b. Weighted standard rate of supply curves. Drainage areas usually consist of combinations of paved and unpaved areas having different infiltration capacities. A weighted standard supply should be established for the composite drainage areas by weighting the standard supply curve numbers adopted for paved and unpaved surfaces in proportion to their respective tributary area.

7-5. Runoff.

a. Limitations. For areas of up to about 1 square mile, and where only peak discharges are required for design and extensive ponding is not involved, computation of runoff will be accomplished by the so-called rational method. For larger areas, the overland flow method should be used.

b. Rational method. In computing runoff by the rational method, use the empirical formula:

$$Q = C(I - F)A$$

where:

Q = peak runoff in cubic feet per second.

C = a coefficient expressing the percentage to which the peak runoff is reduced owing to transitory storage. Its value depends primarily on the general slope and surface irregularity of the tributary area. Accurate determinations of C from available data are not readily made. For most areas, the apparent values range from 0.6 to 1.0. A value of 0.6 may be assumed applicable to areas left ungraded where meandering-flow and appreciable natural-ponding conditions exist, slopes are 1 percent or less, and vegetative cover is relatively dense. A value

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of 1.0 may be assumed applicable to smooth areas of substantial slope with virtually no potential for surface storage and little or no vegetative cover.

I = rainfall intensity in inches per hour for the most critical time of concentration and for the design storm frequency. Time of concentration is generally defined as the time required, under design storm conditions, for runoff to travel from the most remote point of the drainage area to the point in question. In computing time of concentration, it should be kept in mind that, even for uniformly graded bare or turfed ground, overland flow in "sheet" form will rarely travel more than 300 or 400 feet before becoming channelized and thence moving relatively faster. Also, for design, the practical minimum time of concentration for roofs or paved areas and for relatively small unpaved areas upstream of the uppermost inlet of a drainage system is 10 minutes; smaller values are rarely justifiable; and values up to 20 minutes may be used if resulting runoff excesses will not cause appreciable damage. A minimum time of 20 minutes is generally applicable for turfed areas. Further, the configuration of the most remote portion of the drainage area may be such that the time of concentration would be lengthened markedly and thus the design intensity and peak runoff would be effectively decreased. Then, that portion of the drainage area should be ignored and the peak flow computation should be for only the more efficient, downstream portion.

F = infiltration rate in inches per hour following a rainfall of 1 hour. Where F varies considerably within a given drainage area, a weighted rate may be used; it must be remembered, however, that pervious portions may require individual consideration, because a weighted overall value for F is proper for use only if rainfall intensities are equal to or greater than the highest infiltration rate within the drainage area.

A = drainage area in acres.

In Army construction drainage design, factors such as initial rainfall losses and channel percolation rarely enter into runoff computations involving the rational method.

c. Overland flow. The surface runoff resulting from a uniform rate of supply is termed overland flow. If the rate of supply were to continue indefinitely, the runoff would rise to a peak rate and remain constant. The peak rate is established after all parts of the drainage surface are contributing to runoff. The elapsed time for runoff to

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build to a peak is termed the time of concentration and it depends primarily on the surface characteristics as follows: the coefficient of roughness, the slope, and the effective length. When the supply terminates, the runoff rate begins to diminish but continues until the excess stored on the surface drains away.

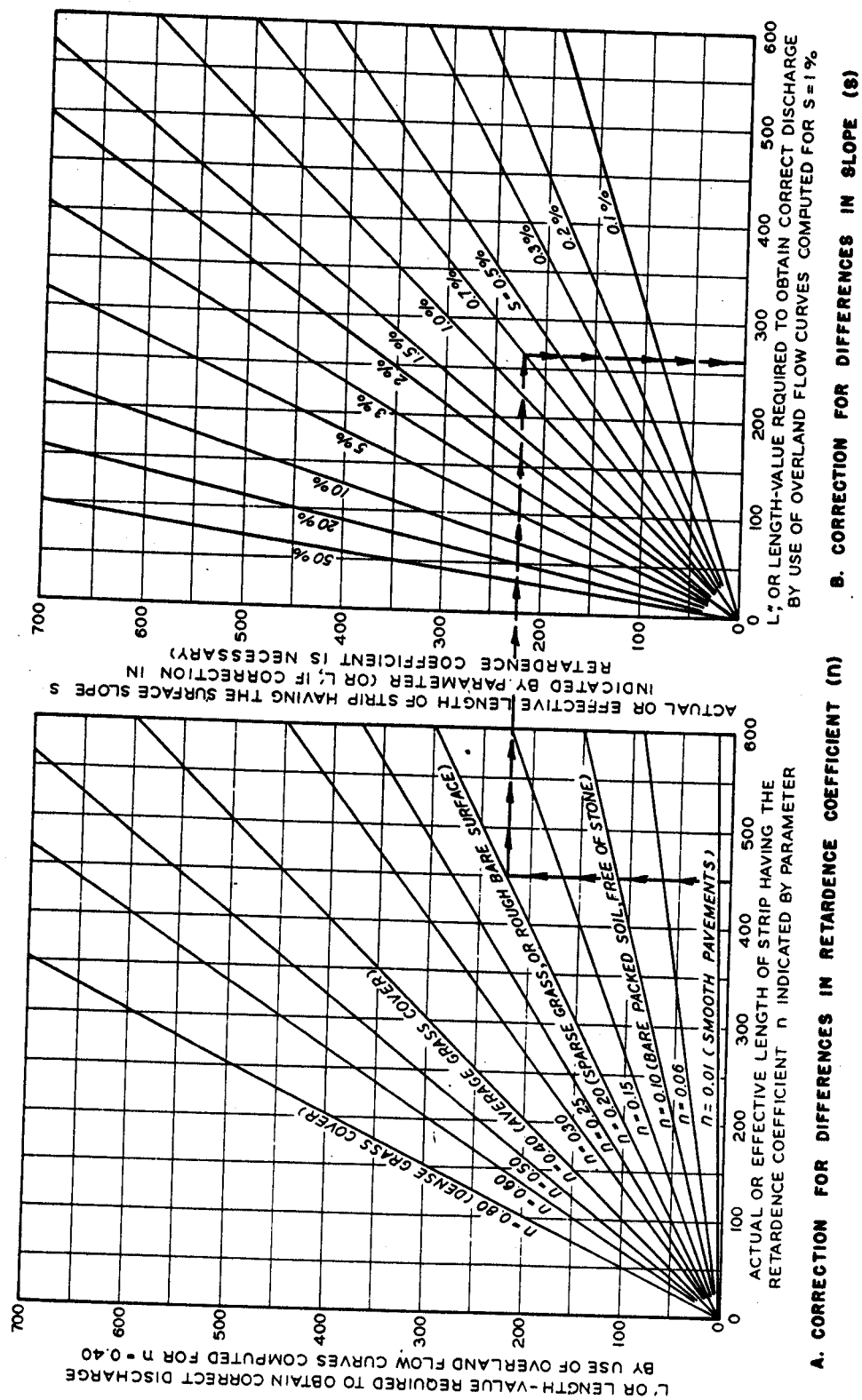
(1) Effective length. The effective length represents the length of overland flow, measured in a direction parallel to the maximum slope, from the edge of the drainage area to a point where runoff has reached a defined channel or ponding basin. In large drainage areas, considerable channelized flow will occur under design-storm conditions. Investigation of many runoff records for watersheds have indicated that by modifying the actual length, satisfactory reproduction of runoff hydrographs may be obtained regardless of channelization of flow. The values for effective length, L , is determined by summing the length of channel flow and the length of overland flow after each has been reduced to an effective length for $n = 0.40$ and $S = 1.0$ percent by means of figure 7-3.

(a) The length of channel flow is measured along the proposed collecting channel for that section in which appreciable depth of flow may reasonably be expected to occur during the design-storm. Length of overland flow is the average distance from the end of the effective channel or from the drain inlet to the edge of the drainage area, measured in the direction of flow as indicated on the proposed grading plans. Grading is such that overland flow will normally channelize in distances of 600 feet or less, although this distance may be exceeded. Whenever the distance is exceeded, the actual length may be divided by a number so that the quotient conveniently falls on the horizontal axis of graph A on figure 7-3. The length derived from graph B on the figure would then be multiplied by this same number to determine the final effective length. Typical values of the coefficient of roughness, n , for use in determining effective length of overland flow are given in table 7-2.

Table 7-2. Coefficients of Roughness for Overland Flow

Surface	Value of n
Pavements and paved shoulders	0.01
Bare packed soil free of stone	0.10
Sparse grass cover, or moderately rough bare surface	0.20
Average grass cover	0.40
Dense grass cover	0.80

(b) For example, to find the effective length of overland flow for an actual length of 900 feet on a sparse grass ground cover, $n = 0.20$, with an overall slope of 0.7 percent, use the following procedure. Divide the 900-foot actual length by the number 2 and enter



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FIGURE 7-3. MODIFICATION IN L REQUIRED TO COMPENSATE FOR DIFFERENCES IN n AND S

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graph A, figure 7-3 with 450 feet on the horizontal axis. Project a line vertically upward until it intersects the coefficient of roughness line; proceed horizontally to the intersection of the slope line equal to 0.7 percent on graph B, and proceed vertically down to obtain a length of 275 feet which must be multiplied by the number 2, resulting in a total effective length of overland flow of 550 feet.

(c) Distances across paved areas may be neglected when calculating effective length.

(2) Runoff rates. The peak runoff rates and critical duration of supply can be obtained from figure 7-4.

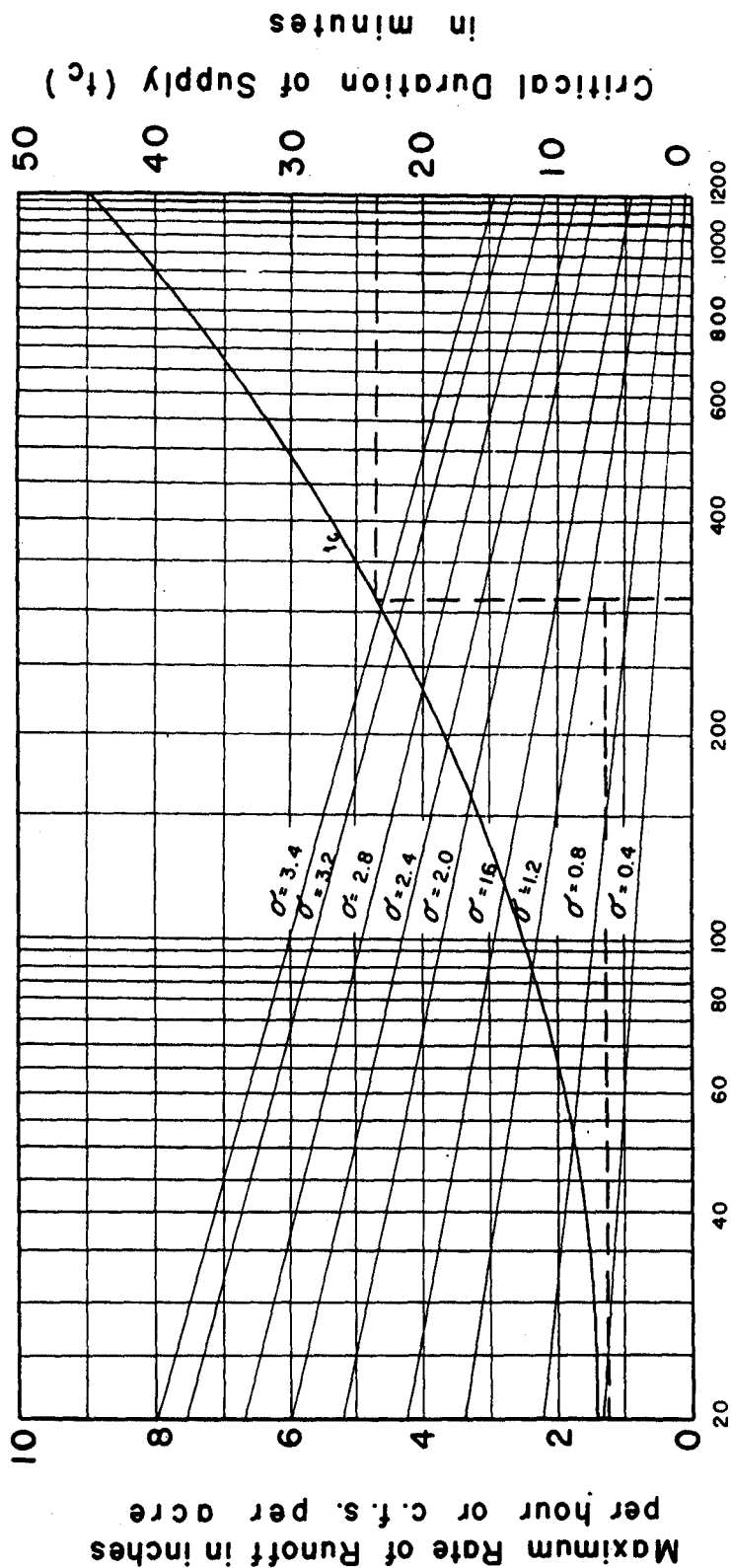
(a) The following example is provided to illustrate the use of figure 7-4. Assume an effective length of overland flow of 315 feet and a rate of supply of 1.0 in/hr. To determine the critical duration of supply, project a line vertically upward from the effective length to the intersection of the t_c line and proceed horizontally to the right to the critical duration of supply which, in this example, is 23 minutes. To determine the maximum rate of runoff, proceed vertically upward from the effective length to the intersection of the rate of supply line and proceed horizontally to the left to the maximum rate of runoff which is 1.2 cfs per acre of drainage area.

(b) The total drainage flow is determined by multiplying the maximum rate from figure 7-4 by the contributing area (in acres).

7-6. Investigations to determine surface drainage requirements.

a. On-site investigation. An on-site investigation of the system site and tributary area is a prerequisite for study of drainage requirements. Information regarding capacity, elevations, and condition of existing affected drains will be obtained. Topography, size, and shape of drainage area, and extent and type of areal development; profiles, cross sections, and roughness data on pertinent existing streams and watercourses; and location of possible ponding areas will be determined. Thorough knowledge of climatic conditions and precipitation characteristics is essential. Adequate information regarding soil conditions, including types, permeability or perviousness, vegetative cover, depth to and movement of subsurface water, and depth of frost will be secured.

b. Maps, charts, photographs, and surveys. Maps and charts showing necessary detailed topography and other essential features of the areas to be drained and outlining the watershed area and subareas for determining runoff quantities will be prepared for layout and design. Aerial photographs including stereoscopic pairs will be used to the maximum practicable extent.



L_E (Equivalent Length of Flow) in Feet with $n = 0.4$ and $s = 1.0\%$

σ = Rate of Supply

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FIGURE 7-4. RATE OF OVERLAND FLOW

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c. Existing utilities. The location, type, size, elevations, and condition of existing utilities in addition to drains that may affect or be affected by the new drainage system will be determined.

d. Snowfall records. Snow cover depths and convertibility factors to inches of rainfall along with rainfall records must be obtained.

e. Runoff records. Runoff records for drainage areas in the same locality having similar characteristics and soil conditions should be utilized.

f. Grading. Proper grading is the most important single factor contributing to the success of the drainage system. Development of grading and drainage plans must be fully coordinated.

g. Soils investigation. Information gathering for soil investigations should be coordinated with subdrainage and other aspects of the overall design.